Symmetry Perception and Psychedelic Experience

Subjects: Psychology

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Neuroscientific studies on symmetry perception have accumulated in the last 20 years. Functional MRI and EEG experiments have conclusively shown that regular visual arrangements, such as reflectional symmetry, Glass patterns, and the 17 wallpaper groups all activate the extrastriate visual cortex. This activation generates an event-related potential (ERP) called sustained posterior negativity (SPN).

Keywords: Psychophysics ; Neuroscience ; Preattentive Processing ; Nature-Nurture ; Aesthetics ; Psychedelics ; Symmetry ; Regularity

1. Introduction

Symmetry perception has been studied since the early observations of Ernst Mach, who noticed that reflectional symmetry is more salient than translation or rotation, particularly when the axis is vertical (**Figure 1**). The Makin et al. [1] review on symmetry perception has six parts: 1) psychophysics, 2) neuroimaging, 3) automaticity, 4) innateness, 5) beauty, and 6) psychedelic experience.

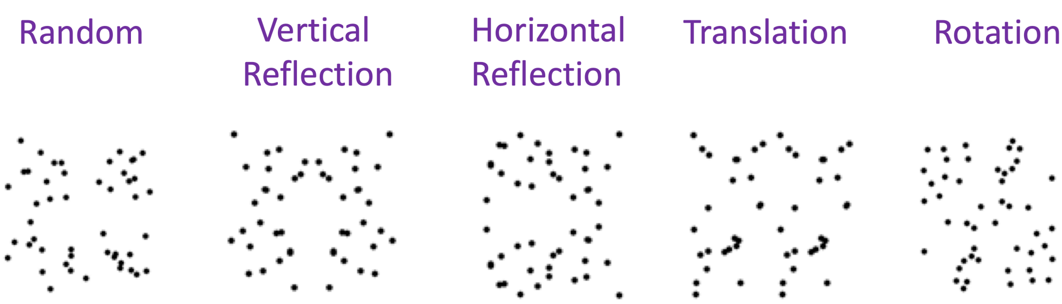

Figure 1. Dot patterns with different kinds of visual symmetry.

1.1. Part 1: Psychophysical Research on Symmetry Perception

In a typical psychophysical experiment, the participants view many trials with abstract patterns (like those in **Figure 1**). On some trials the patterns are symmetrical, on some trials they are random. The participant’s task is to discriminate between these categories as quickly and accurately as possible. Response times are faster for more salient kinds of symmetry, such as vertical reflection.

Another typical psychophysical procedure is the 2-interval forced choice task. Here each trial involves two brief intervals. Symmetry is presented in one interval, and asymmetry in the other. The task is to determine which interval contained more symmetry – first or second. The symmetry-asymmetry difference is then systematically varied to determine discrimination thresholds (e.g., 75% correct). Discrimination thresholds are lower for more salient symmetries, such as vertical reflection [2].

Reflectional symmetry detection is very efficient and noise tolerant [3]. Perfect reflectional symmetry can be discriminated from complete asymmetry within a single screen refresh (e.g., 16.67 ms on a 60Hz monitor) or a single fixation [4]. However, the difference between perfect reflection and slightly imperfect reflection is not perceptually obvious and may only be noticed with serial visual search [5] [6].

Psychophysical procedures have often been used in studies supporting filter models of symmetry perception. The early visual system is like a retinotopic array of spatial frequency and orientation tuned filters [7]. When an image is subject to such filtering, any region with reflectional symmetry will yield mid-point-colinear blobs orthogonal to the global axis. This is true whether the symmetrical region is caused by an abstract pattern or a real object. Universal symmetry detection could be a matter of estimating blob alignment [8]. Early work in this field found that low frequency reflection dominates high frequency reflection when the two are superimposed at different orientations [9] and that filtered information in an elongated 'integration region' around the axis particularly important [10]. There have been many proposed filter models [11][12][13], and comparable accounts of Glass pattern detection have also been advanced [14].

Filter models have biological plausibility allow precise simulations, but there are many facts about symmetry detection they cannot explain (**Figure 2**). First, without modification, they cannot explain sensitivity to some kinds of anti-symmetry, where luminance is reversed across the axis [15]. Second, filter models cannot explain the well-established interaction between regularity and objecthood: Contour reflection is more salient when the contours belong to one object, while contour translation is more salient when they belong to two separate objects [16] [17]. Third, filter models cannot explain sensitivity to extraretinal symmetry, caused by partial occlusion [18] or perspective distortion [19]. Finally, different mechanisms are required to detect symmetry in radial frequency contours [14] or optic flow fields [20]. In summary, filter models can explain some, but not all aspects of symmetry detection.

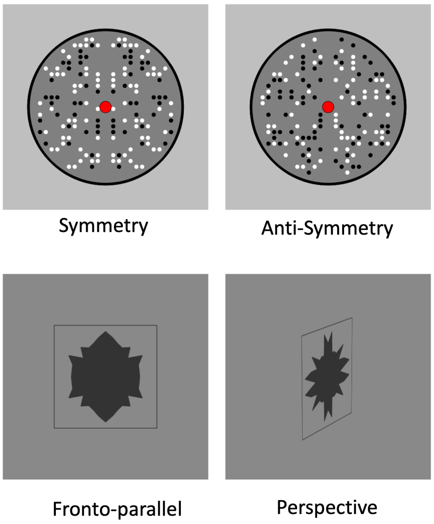

Figure 2. Examples of symmetry and anti-symmetry (top) and symmetrical polygons seen from different view angles. The stimuli on the right are less obviously symmetrical, and they are a challenge for filter models.

1.2. Part 2: Neural Responses to Visual Symmetry

The brain response to visual symmetry has been studied extensively in the last 20 years [21]. Functional MRI work has shown that symmetry activates a network of regions in the extrastriate visual cortex, centred on V4 and the lateral occipital complex [22][23][24][25][26]. This extrastriate symmetry response can also be measured with EEG (**Figure 3**). Both symmetrical and asymmetrical stimuli generate event related potentials (ERPs) at posterior electrodes. After the P1 and N1 components of the visual evoked potential, amplitude is lower for symmetrical stimuli. This symmetry-asymmetry difference wave was observed by Jacobsen and Höfel [27], and is now called the Sustained Posterior Negativity (SPN) [28]. When symmetry is presented on one visual hemifield, the SPN is generated in the contralateral hemisphere [29]. A high amplitude SPN is one where the symmetry-asymmetry difference wave falls far below zero. As seen in Figure 3, SPN amplitude scales with the proportion of symmetry in the image and with the perceptual goodness of different visual regularities [30]. However, the SPN is robust to experimental manipulations of task [31].

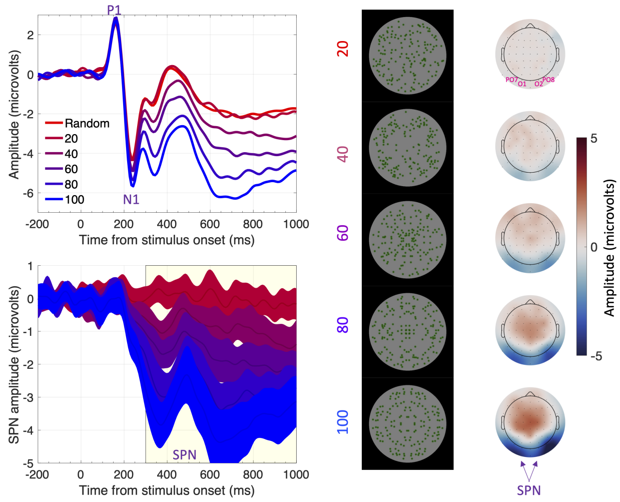

Figure 3. The grand-average ERPs are shown in the upper left panel and difference waves (reflection-random) are shown in the lower left panel. A large SPN is a difference wave that falls a long way below zero. Topographic difference maps are shown on the right, aligned with the representative stimuli (black background). The difference maps depict a head from above, and the SPN appears as blue at the back. Purple labels indicate electrodes used for ERP waves [PO7, O1, O2 and PO8]. Note that SPN amplitude increases (that is, becomes more negative) with the proportion of symmetry in the image. In this experiment, the SPN increased from 0 to ~-3.5 microvolts as symmetry increased from 20% to 100%.

The SPN is closely related to a negativity extracted from steady state visual evoked potential methods [32][33][34].

Many SPN data sets are now available on a public databased called The Complete Liverpool SPN Catalogue (https://osf.io/2sncj/). This database houses EEG data and analysis scripts from all SPN projects at University of Liverpool, both published and unpublished.

1.3. Part 3: Symmetry Detection Can be Automatic, Preattentive and Unconscious

Symmetry does not pop out in classic visual search tasks [35] and it often go unnoticed in priming studies [36]. Despite these observations, researchers believe that stronger kinds of visual symmetry are sometimes processed automatically, preattentively, and unconsciously. There are several lines of evidence for this. First, insects use symmetry to guide adaptive behaviour [37] and insects are probably unconscious. Second, specific neurons in area V4 respond to specific kinds of symmetry in unconscious anesthetised monkeys [38]. Third, hemispatial neglect patients unconsciously use symmetry in figure-ground segmentation, even though half the object is subjectively absent [39]**.** Finally, symmetry is a gestalt grouping principle [40] [41] and resulting representations presumably guide thousands of judgments, saccades, and actions per day. These routine sensory-motor object interactions happen without anyone consciously attending to the symmetry itself.

Claims about the automaticity of symmetry detection should always be qualified by specifying the type of symmetry in question. For instance, what is true of single axis symmetry may not be true of double axis symmetry.

1.4. Part 4: Reflectional Symmetry Sensitivity is Innate

Perhaps reflectional symmetry perceptually special because genes hardwire the brain with innate reflection detectors? Good answers to nature-nurture questions are always likely to be subtle, but this bold nature claim might be a reasonable first approximation. After all, there is evidence for reflectional symmetry sensitivity in newly hatched poultry chicks [42]. Meanwhile, preferential looking and habituation studies on human infants suggest symmetry sensitivity at 4 months [43] [44]. Pornstein and Krinsky [45] found that infants are more sensitive to vertical reflection than other regularities. In contrast, Deep Neural Networks (DNNs) struggle to classify reflectional symmetry in exemplars outside their training set [46]. Many lines of research suggest DNNs overweight local cues, and are insensitive to global, configural properties [47]. Symmetry is a paradigm example of a configural property.

1.5. Part 5: Aesthetic Significance of Symmetry

Many animals seek mates with symmetrical phenotypic features. This is possibly because symmetry indicates health and genetic fitness [48], although there are alternative evolutionary explanations[49][50]. Humans are attracted to symmetrical faces and bodies [51] [52], although it can be difficult to separate facial symmetry and prototypicality.

Many studies in empirical aesthetics show that symmetry adds to the appeal of abstract patterns [53] [54] [55]. It is unclear whether innate sexual attraction to facial symmetry overgeneralizes to abstract patterns (in the same way that the innate 'cuteness' reaction to babies overgeneralizes to miniature objects). It is possible that symmetry-phiia in the face domain and symmetry-philia in the abstract pattern domain are two distinct psychological phenomena [56]. While the neural response to symmetry is preattentive, aesthetic evaluation of symmetry may only happen when symmetry is attended and classified [57] [58]. Symmetry may be an aesthetic primitive, which is appreciated in all cultures. However, artists and art experts may cultivate a taste for abstract asymmetry [59].

1.6. Part 6: Symmetry and Psychedelic Experience

Visual symmetry is prominent in hallucinations induced by the psychedelic drug N, N-dimethyltryptamine (DMT). DMT is an ingredient in the potent South American hallucinogen ayahuasca, and it is pharmacologically related to other more famous serotonergic drugs like LSD and Psilocybin (the active ingredient in magic mushrooms). Unlike LSD, DMT is an endogenous neurotransmitter found in healthy brains. It could be that individual differences in endogenous DMT signalling contribution to individual differences in aesthetic sensitivity and religiosity.

DMT experience was analysed by Lawrence et al. [60], who found that symmetry and fractal geometry are common hallucinations. A qualitative interview study by Cott and Rock [61] corroborates this. One participant reported that:

“The entire room was crawling with beautiful geometric hallucinations.”

Another participant reported:

“The room erupted in incredible neon colors, and dissolving into the most elaborate incredibly detailed fractal patterns that i [sic] have ever seen”.

The abundance of geometry is obvious in DMT inspired art (https://www.alexgrey.com/).

A representative account of DMT phenomenology was compiled by Gomez-Emilsson [62], who discussed six stages of the DMT trip. At stage 1 (Threshold) colours become vivid and visual acuity subjectively sharpens. At stage 2 (The chrysanthemum), colourful slowly rotating kaleidoscopes and mandalas are salient when users close their eyes. If you keep your eyes open, surfaces ‘symmetrify beyond belief’. At stage 3 (The magic eye) surfaces may develop autostereogram properties, where depth separation breaks up the 2D surface. Any regular structure is prone to overflow and fractalize. At Stage 4 (The waiting room) immersion hyperspace becomes intense, and there is a subjective sense of communicating with supernatural beings. At Stage 5 (The breakthrough) impossible hyper dimensionality and space-time tunnelling are experienced. The telepathic agents melt from human form are fuse with the hyper-dimensional geometry. The new universe feels palpably panpsychic, as if made of sentient material. Stage 6 (Amnesia) is apparently indescribable, because no visual representations or linguistic descriptions are adequate, and without these familiar cognitive tools, it is hard to reconstruct memories.

It is unlikely that all DMT users have the same six stage trip, but this account is representative, and it highlights the salience of symmetry in DMT hallucinations.

As research into psychedelic drugs becomes mainstream again, researchers anticipate more interest in hallucinatory symmetry. One possibility is that DMT reduces backward travelling alpha waves, so that the visual cortex is disinhibited, and internally generated representations cascade up the visual hierarchy [63].

Visual flicker is a cheaper and safer way to experience hallucinatory symmetry. Spatially unstructured flickering light often produces simple geometry, such as fans, tunnels, and spirals (**Figure 4**)[64]. Such patterns, labelled as ‘form constants’, could be an emergent property of overexcited retinotopic visual maps [65].

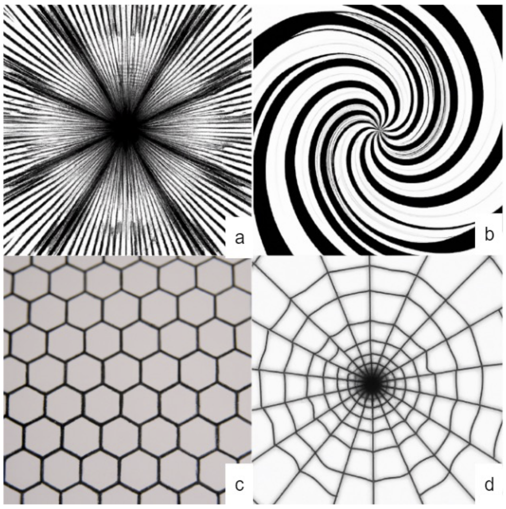

Figure 4. Artistic representations of form constants**:** a) tunnel/funnel; b) spiral; c) honeycomb; d) cobweb.

2. Summary

As researchers concluded in the review paper, the psychedelic renaissance opens new doors for symmetry perception research.

What would the extrastriate symmetry network do if there was no sensory input, and no top-down inhibition? Perhaps it would not simply remain silent by default. Instead, it may spontaneously generate a kaleidoscope of colourful, geometrical representations. Psychedelic drugs may disinhibit the extrastriate cortex, so the internal kaleidoscope intrudes on conscious experience.

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